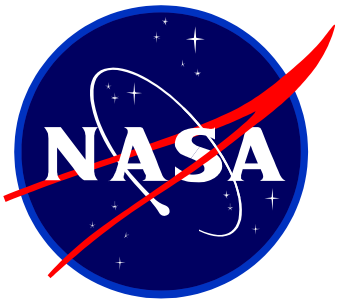

Joint NASA/DOD Work Plan on Orbital Debris

2004 Revision

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1. Background

1.1 Purpose

The NASA/DOD orbital debris work plan was originally developed in 1997 in response to recommendations in the U.S. Government *Interagency Report on Orbital Debris -1995*. The Interagency report laid out the technical objectives necessary for the U.S. Government to demonstrate its leadership role in minimizing the creation of orbital debris consistent with mission requirements and cost effectiveness. Specifically, the Interagency report recommended continued U.S. Government activities in the following three areas:

- Improving our understanding and monitoring of the debris environment through an appropriate mix of measurements and simulations;
- Working with other government agencies and with industry on voluntary design guidelines to minimize the future creation of orbital debris; and
- Working with other spacefaring nations and international organizations to adopt common debris minimization practices.

Both NASA and DOD have ongoing programs regarding orbital debris monitoring, research, and mitigation. The purpose of this work plan is to promote coordination between these independent programs. As in the past, each party shall bear the cost of fulfilling its respective responsibilities, dependent upon the availability of appropriated funds.

This background section focuses on the essential findings of the 1995 revision of the Interagency study on orbital debris. These findings highlight changes that occurred following the publication of the 1989 *Report on Orbital Debris* by the Interagency Group (Space). Five recommendations were proposed in the 1995 report to address issues raised during the revision. This joint NASA/DOD work plan addresses the first of these recommendations.

1.2 1995 Interagency Report Findings and Recent Activities

The 1989 *Report on Orbital Debris* noted the ambiguities of measurements on the debris environment. Since that time NASA, with the assistance of DOD, has continued to conduct measurements of the low Earth orbit (LEO) debris environment. Through these efforts a better assessment of the orbital debris environment in LEO has emerged. A new environment engineering model was adopted by NASA in 1996, and it is now employed by many US Government agencies and industry, as well as by foreign organizations. A revised environment engineering model, based upon a more extensive measurements database and improved computational capabilities, was completed in 2001. NASA has implemented, in cooperation with the Inter-Agency Space Debris Coordination Committee (IADC), an exploratory campaign to measure the debris environment near the geosynchronous (GEO) regime. Efforts should continue in order to refine our understanding of the current environment as well as to monitor changes in the environment with time. Contributions to the current debris environment continue to be essentially proportional to the level of space activity by a given spacefaring nation.

NASA and DOD have expended considerable effort to monitor the near-Earth environment. One of the primary means involves the use of the DOD Space Surveillance Network (SSN), composed of radar and optical sensors supplying data to command and control facilities. The SSN tracks over 12,000 objects in orbit, most of which are debris. It should be noted that today the SSN is primarily focused on meeting operational national security requirements; because of this, the time spent using the network for debris research is limited. Also, the SSN was not designed to globally detect and track small debris objects. A good example of NASA/DOD cooperation to collect debris data is the modification of the Haystack radar and the development of the Haystack Auxiliary (HAX) radar for orbital debris measurements. These radars have greatly enhanced our ability to sample the LEO debris environment and are essential for sampling and estimating the very hard to observe 1-10 cm debris population in LEO. Because there are few sensors devoted to the debris task and not all debris can be tracked, statistical models must be used to characterize the current debris population at LEO and GEO below the sizes routinely observed.

The development and utilization of statistically based predictive models has improved. For example, NASA has continued the development of its engineering model and its evolutionary environment model, EVOLVE. In 1999 NASA completed development of a data-based, higher fidelity breakup model and incorporated it into the new EVOLVE, version 4.0. The results of our improved predictive capability, when combined with our increased knowledge of the debris environment, suggest that failure to take any mitigation action could lead to a continuing increase in orbital debris in the coming years. The outcomes of these simulations vary depending on the initial assumptions and the space traffic model employed. Assuming a continuation of launch activity at the same average rate as over the last ten years, average future solar cycles, and future operational practices that will reduce but not eliminate the possibility of explosions in orbit, most models predict an increase in orbital debris. Similarly, most models indicate that the use of operational practices to limit the orbital lifetime of spent upper stages and payloads and the depletion of residual energy sources at end-of-mission have the potential to significantly mitigate the growth of orbital debris.

The 1996 U.S. Government space policy requires all space sectors to seek to minimize the creation of orbital debris consistent with mission requirements and cost effectiveness. In 1995 NASA expanded its agency policy on orbital debris with a comprehensive set of guidelines and assessment procedures. U.S. Space Command during 1997-1998 and NRO in 1999 issued similar orbital debris mitigation directives and instructions. A DOD-wide instruction addressing orbital debris issues was issued in 2000. Both NASA and DOD guidance are consistent with the current national orbital debris policy.

The 1996 U.S. Government space policy (PDD-NSC-49/NSTC-8, 14 September 1996) directs that the U.S. Government take a leadership role in the appropriate international fora to encourage other nations to adopt policies and practices similar to those of the U.S. Government. The United States and other spacefaring nations have initiated voluntary design measures (e.g., tethering of operational debris and the use of debris-free devices for separation and release), as well as operational procedures to reduce the generation of orbital debris, consistent with mission requirements and cost effectiveness. The IADC, comprised of the space agencies of 10 nations as well as ESA, completed its development of consensus orbital debris mitigation guidelines in 2002. These guidelines were then presented to the United Nations in 2003. The United States

considers the development of technical cooperation and consensus to be an important step toward any potential international guidelines relating to orbital debris.

1.3 1995 Interagency Report Recommendations and Response

In light of the findings contained in the *Interagency Report on Orbital Debris - 1995* and noting the progress that has been made in our understanding of the debris environment, the report made the following recommendations:

"Continue and Enhance Debris Measurement, Modeling, and Monitoring Capabilities"

"Our ability to fully understand the orbital debris problem will depend upon our continuing capabilities to measure, model, and monitor the debris environment. NASA and DOD should continue current investments in their debris research programs and, as resources permit, seek to expand existing measurement capabilities (both radars and optical systems) and bring new systems now under development on line as soon as possible. NASA should continue its program of returned material analysis and seek additional opportunities to exchange samples with other spacefaring nations. DOD and NASA should closely coordinate their laboratory studies of breakups from explosions and collisions. Particular attention should be given to those orbits where critical national security payloads may be located, where permanent presence is planned (i.e., the Space Station), in geosynchronous orbits, and in the economically and scientifically critical sun-synchronous orbits."

Response: This work plan addresses these recommendations through an approach that includes (a) using NASA's on-going measurement and modeling programs as a baseline and, as feasible, supplementing the environmental assessments with results from DOD measurements, (b) monitoring the long-term trends of current mitigation practices, (c) continued analysis of Haystack and HAX radar measurements, as well as other sensor and spacecraft surface data, with the goal of reducing the uncertainties in estimating the LEO small debris population, and (d) conducting searches for orbital debris in high altitudes.

"Conduct a Focused Study on Debris and Emerging LEO Systems"

"To date, government involvement has focused primarily on the frequency licensing issues associated with these systems. To ensure that other considerations pertinent to these systems are adequately understood and reviewed, NASA, with the participation of DOD, DOT, DOC, and other relevant federal agencies, should convene a workshop with U.S. industry on debris mitigation and LEO systems. The workshop should serve as a first step in identifying possible measures for debris mitigation that LEO operators could incorporate in the design of future systems. The workshop could also identify possible mitigation measures for launch vehicle operators contemplating service for LEO systems. This effort should include appropriate analysis of the economic

impacts that specific mitigation measures could have on the satellite and launch vehicle communities. NASA should document the results from this workshop in a report and factor these results into government/industry efforts to develop guidelines on debris mitigation (see Recommendation 3)."

Response: NASA developed the CONSTELL model for examining orbital debris issues associated with the operation of satellite constellations in LEO. The results of the subsequent preliminary analyses were presented at the U.S. Government Orbital Debris Workshop for Industry, held in Houston, 27-29 January 1998. NASA and DOD continue to evaluate orbital debris issues for constellations through the use of the NASA EVOLVE model and through action items and regular meetings of the IADC.

"Develop Government Design Guidelines on Orbital Debris"

"NASA has made substantial progress in documenting and defining specific design measures that can be taken into account during the development of spacecraft and launch vehicles in order to minimize or eliminate debris generation. Using this initial work, NASA and DOD should jointly develop draft design guidelines that could serve as a baseline for agency requirements for future spacecraft and launch vehicle/service procurements. Upon completion of the draft guidelines, NASA and DOD should disseminate the draft to industry for comment and convene a workshop to discuss industry and government concerns. This workshop should also seek to identify design guidelines that would require international consensus in order to ensure a fair and level playing field. The goal of the exercise would be development of the Government/ Industry guidelines that both sectors could use in the design and development of future systems."

Response: During 1997 NASA and DOD, with assistance from other U.S. Government agencies, developed the draft U.S. Government Orbital Debris Mitigation Standard Practices. These standard practices were presented at the U.S. Government Orbital Debris Workshop for Industry, held in Houston, 27-29 January 1998. During 1999 and 2000 NASA and DOD representatives briefed senior management of leading US aerospace companies and the Space Council of the Aerospace Industries Association (AIA) about the importance which the US Government places on orbital debris mitigation and about the nature and implementation of the US Government orbital debris mitigation standard practices. NASA and DOD are continuing their efforts to forge international voluntary orbital debris mitigation guidelines through the IADC and the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS).

"Develop a Strategy for International Discussions"

"Since the 1989 report was issued, three important international developments related to debris have taken place. First, through NASA's efforts, an international agency-level organization (the Inter-Agency Space Debris Coordination Committee, IADC) has been formed to facilitate the exchange of technical research and information related to debris. The United States, Japan, ESA, Russia, and China currently have agency-level representation on the committee. Planning for membership of other spacefaring nations is underway. Second, the United States introduced detailed analysis on the problem of the safing and disposal of geostationary satellites to relevant working groups in the International Telecommunication Union (ITU). Third, the United States joined consensus with other members of the Scientific and Technical Subcommittee of the United Nations Committee on Peaceful Uses of Outer Space (COPUOS) to take up the subject of space debris as a formal agenda item.

"The United States should maintain its leadership role in these forums, but seek to do so in a more coordinated and comprehensive way. The Department of State and NASA, with the participation of other relevant agencies, should co-chair a review to develop a strategy outlining how the United States should seek to encourage other spacefaring nations to adopt debris policies and practices and how current bilateral and multilateral discussions can be better coordinated. In developing this strategy the United States government should take into account the need to ensure that a level playing field is created in the application of international orbital debris mitigation policies and practices."

Response: The IADC has been expanded to 11 members with the addition of delegations from France, Germany, India, Italy, the United Kingdom, and Ukraine. DOD became an official part of the NASA delegation in 1996. The IADC meets annually to share technical information and to coordinate joint work in the areas of measurements, modeling, protection, and mitigation. The initial work of the UN COPUOS STSC was completed in February 1999 with the adoption in-full of a report on the world state of orbital debris measurements, modeling, and mitigation. A new multi-year work plan for UN COPUOS STSC was adopted in February 2001. NASA, DOD, and the Department of State developed in 2000 a consensus Interagency strategy for addressing orbital debris issues domestically and internationally.

"Review and Update U.S. Government Policy on Debris"

"National Space Policy Directive-1 (NSPD-1), signed in 1989, includes an Intersector Policy guideline calling on agencies to "seek to minimize the creation of space debris." Under NSPD-1, design and operation of space tests, experiments, and systems will strive to minimize or reduce accumulation of space debris consistent with mission requirements and cost effectiveness. NSPD-1 calls on the government to encourage other spacefaring nations to adopt policies and practices aimed at debris mitigation and minimization.

"On June 2,1995, the President directed the OSTP and NSC to lead a comprehensive review of national Space Policy, including policies affecting the civil, commercial, and national security space sectors. As part of this review, the Administration should seek to translate the recommendations contained in this report, as appropriate, into national policy concerning agency programs and activities related to orbital debris."

Response: On September 14, 1996, the President signed the new National Space Policy. As part of this review to prepare the new policy, the Administration translated, as appropriate, findings and recommendations contained in the 1995 Interagency report on orbital debris into the new National Space Policy. This work plan is consistent with this policy.

The National Space Policy contains the following two paragraphs concerning agency programs and activities related to orbital debris:

> "The United States will seek to minimize the creation of space debris. NASA, the Intelligence Community, and the DOD, in cooperation with the private sector, will develop design guidelines for future government procurements of spacecraft, launch vehicles, and services. The design and operation of space tests, experiments and systems, will minimize or reduce accumulation of space debris consistent with mission requirements and cost effectiveness.
>
> "It is in the interest of the U.S. Government to ensure that space debris minimization practices are applied by other spacefaring nations and international organizations. The U.S. Government will take a leadership role in international fora to adopt policies and practices aimed at debris minimization and will cooperate internationally in the exchange of information on debris research and the identification of debris mitigation options."

2. Joint NASA/DOD Work Plan

This section presents an integrated Joint NASA/DOD Work Plan to address Recommendation 1 of the *Interagency Report on Orbital Debris - 1995* and to provide a framework for cooperative NASA/DOD research, monitoring, modeling, and mitigation activity regarding orbital debris. NASA and DOD will remain individually responsible for defining and executing the orbital debris programs of their respective agencies.

This plan will be reviewed on an annual basis and updated as required. This plan also serves to establish the NASA/DOD Orbital Debris Working Group, co-chaired by NASA and DOD. The specific task elements are contained in Appendix A.

2.1 NASA/DOD Orbital Debris Working Group Organization

The NASA/DOD Orbital Debris Working Group will be co-chaired by the NASA Orbital Debris Program Manager and by the Chief, Counterspace Operations Division, HQ Air Force Space Command. Full working group meetings will be held annually, alternating between Houston and Colorado Springs. The agenda and minutes of each meeting will be prepared jointly by the co-chairs. Attendance at the working group meetings will be coordinated by the co-chairs and may include representatives of any NASA, DOD, or Intelligence Community organization, including direct support contractors. At a minimum, participation is expected to include personnel from HQ USSTRATCOM, HQ AFSPC, Space and Missile Systems Center, 1 Space Control Squadron, and NASA Johnson Space Center.

Between annual meetings, the co-chairs may address specific orbital debris issues as necessary and respond to actions assigned at the annual meetings. In particular, the co-chairs will be responsible for responding to requests directed to the NASA/DOD Orbital Debris Working Group by NASA/DOD Partnership Council.

2.2 NASA/DOD Orbital Debris Working Group Objectives

In accordance with Recommendation 1 of the *Interagency Report on Orbital Debris – 1995*, the objectives of the NASA/DOD Orbital Debris Working Group are

(1) to provide information on the respective agency efforts to measure segments of the orbital debris population by ground-based and space-based sensors and by the examination of spacecraft surfaces;

(2) to coordinate, when practical, orbital debris measurement campaigns, e.g., bilaterally or under the auspices of the IADC;

(3) to exchange orbital debris measurement data for the purpose of developing a consensus assessment of the orbital debris environment;

(4) to investigate methods to improve the detection and/or tracking of potentially hazardous debris in both low and high altitude orbits;

(5) to share information on the respective agency efforts to model the present and projected orbital debris environment;

(6) to exchange experimental, observational, and modeling data regarding the creation of debris generated from on-orbit explosions and collisions, to include events categorized as breakups or anomalous events;

(7) to identify orbital debris mitigation guidelines and techniques, both design and operational;

(8) to identify new debris monitoring capabilities that could enhance debris tracking and environment sampling and to improve methods for exchanging data from such systems; and

(9) to share plans for any test, experiment, or other activity which could result in the creation of numerous debris which might pose a hazard to US national space assets.

Appendix A

Specific NASA/DOD Work Elements

Task Number/Name	Task Description
Task 1 NASA/DOD Coordination	Recognizing that NASA/DOD technical coordination in support of US Government Interagency issues, the IADC and UN COPUOS is beneficial, the NASA/DOD Orbital Debris Working Group should meet annually to review agency efforts in orbital debris operations and research. This Working Group will recommend tasks of mutual interest, review work plan task status, identify members to implement work plan tasks, and prioritize the tasks, consistent with available resources.
Task 2 Measuring/Monitoring the Orbital Debris Environment	In accordance with the AFSPC-NASA support agreement on orbital debris data collection, DOD and NASA will ensure future Haystack/HAX measurement/monitoring obligations are fulfilled through 2010. This is necessary to ensure that NASA and DOD (a) can reduce further the uncertainties in current orbital debris population assessments; (b) can continue to accurately monitor the orbital debris population; and (c) have sufficient time to react to any degradation in the orbital debris environment.
Task 3 Implement NASA/DOD Partnership Council Debris Task Team Recommendations	In response to a NASA/DOD Partnership Council Debris Task Team recommendation, DOD and NASA will work to improve the capability of the SSN to track small debris. Key aspects include use of debris detection modes at certain sensors and implementation of certain debris procedures at sensors and command centers.
Task 4 Evaluation of Haystack Data	Annually, NASA will provide Air Force Space Command with small debris observational data collected by the Haystack radar. Completion of this task is necessary to maintain a consensus on estimates of the orbital debris population below 10 cm.
Task 5 Exchange of Orbital Debris Models	NASA and DOD will exchange orbital debris model updates to foster a better common understanding of modeling efforts and to permit independent assessments of orbital debris populations and hazards.

Task 6 Identification of Upgrades to the Space Surveillance Network	DOD will continue to identify Space Surveillance Network (SSN) sensor and SSC/ASSC calibration and processing upgrades to enhance orbital debris data collection and processing on objects not currently in the satellite catalog. These data are required to increase the quantity of data collection on small orbital debris objects. These data will also push the deterministic orbital debris data to lower sizes, thus enhancing the collision avoidance prediction capability of the SSN.
Task 7 Increasing Orbital Debris Measurements	NASA and DOD will seek to increase orbital debris measurements of low inclination, GEO, Molniya, and GEO transfer orbits. Special observation campaigns may also be undertaken to support statistical assessments of the small debris in these regimes. These data are required to address current population uncertainties.
Task 8 New Debris Measurement Systems	NASA and DOD will pursue, on an on-going basis, methods to obtain additional data from sensors having detection capabilities similar to those of the Haystack and Haystack Auxiliary radars. This is required to improve orbital debris models.
Task 9 Improving Knowledge of Orbital Debris	NASA and DOD will continue efforts to increase knowledge of size, shape, mass, and composition of debris with emphasis on detection, precision tracking by multiple radar frequencies, multi-spectral data collection, polarization measurements, time-history of cross section data, and orbit decay analysis.

Appendix B

Record of NASA/DOD Orbital Debris Working Group Meetings

13-14 January 1998	**Colorado Springs**
9 February 1999	**Colorado Springs**
25-26 January 2000	**Houston**
17 April 2001	**Colorado Springs**
6 February 2002	**Houston**
22 May 2003	**Colorado Springs**
29 January 2004	**Houston**